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Angostura Reservoir
Fall River County
South Dakota

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT
ON
ANGOSTURA RESERVOIR
FALL RIVER COUNTY
SOUTH DAKOTA
EPA REGION VIII
WORKING PAPER No. 600

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

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WITH THE COOPERATION OF THE

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND THE

SOUTH DAKOTA NATIONAL GUARD

JANUARY, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

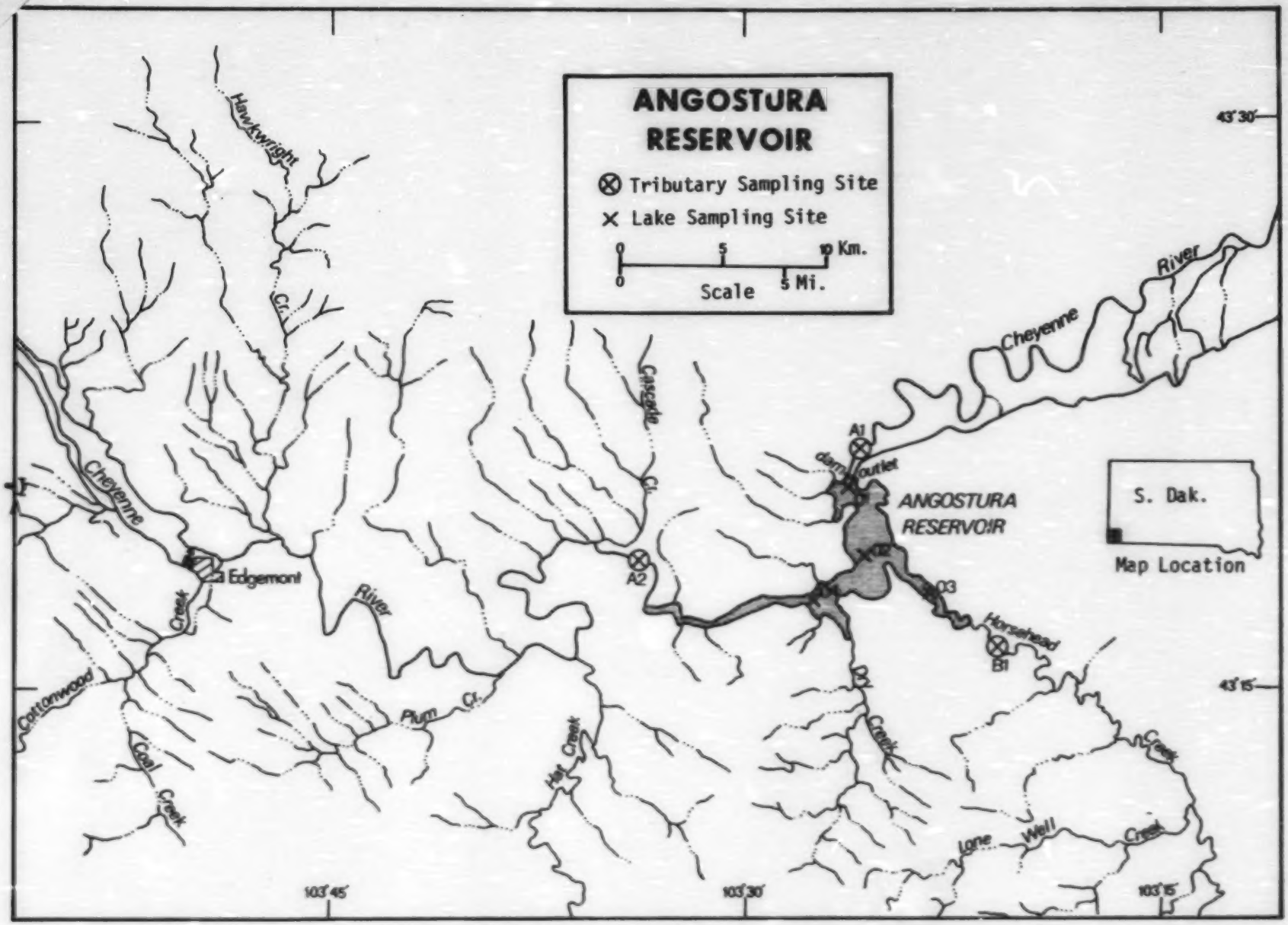
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

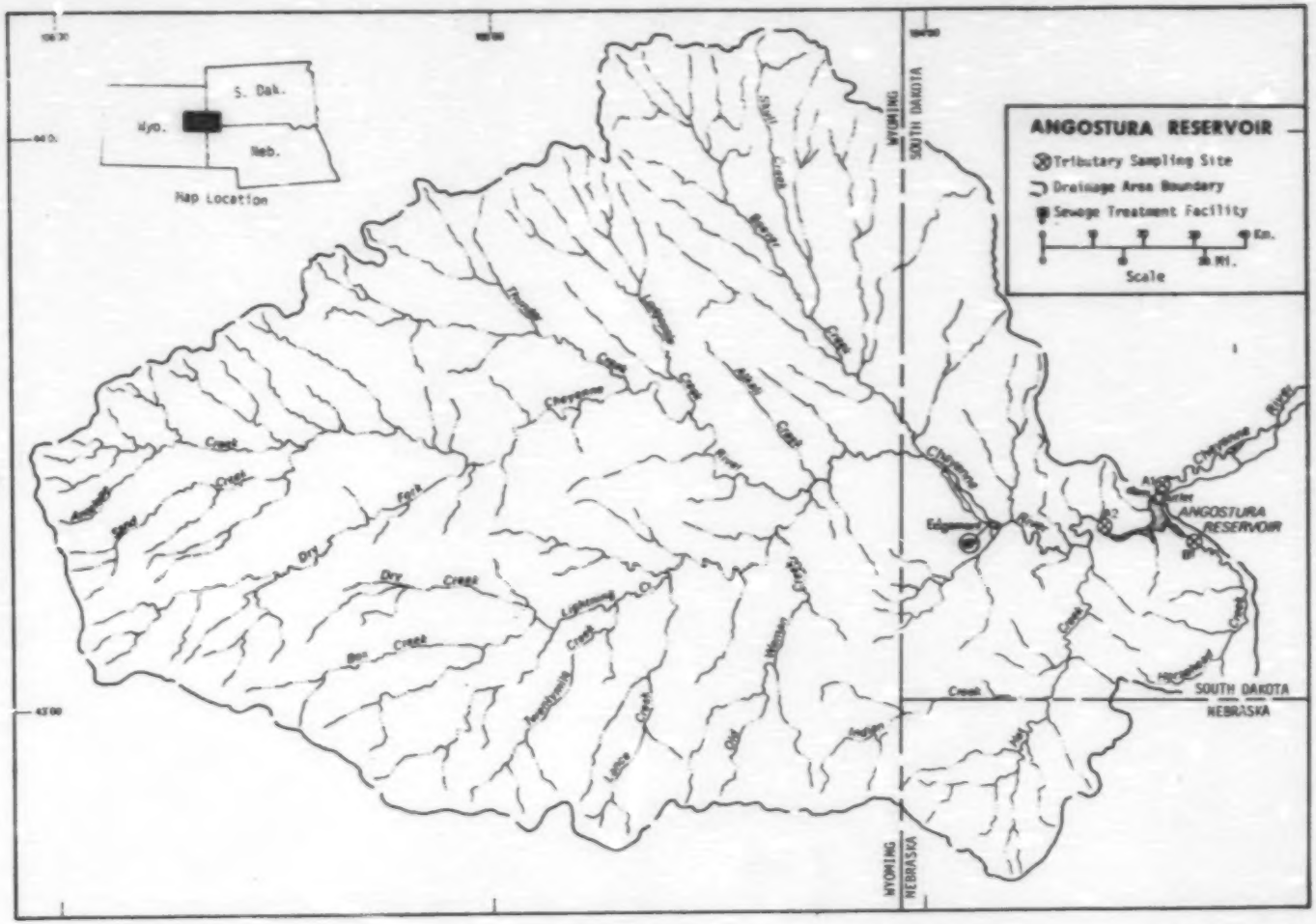
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


ANGOSTURA RESERVOIR
Tributary Sampling Site
Lake Sampling Site
0 5 10 Km.
0 5 Mi.
Scale
S. Dak.
Map Location
ANGOSTURA RESERVOIR
Cheyenne River
Hawkwright Cr.
Cascade Cr.
Cheyenne Creek
Edgemont
Cottonwood Creek
Coal Creek
Plum Cr.
Hat Creek
Dry Creek
Horsehead Creek
Lone Well Creek
A1
A2
B1
dam outlet
43°30'
43°15'
103°45'
103°30'
103°15'


ANGOSTURA RESERVOIR
Tributary Sampling Site
Drainage Area Boundary
Sewage Treatment Facility
Scale
Km.
Mi.
S. Dak.
Wyo.
Neb.
Map Location
WYOMING
SOUTH DAKOTA
NEBRASKA
ANGOSTURA RESERVOIR
Cheyenne River
Edgemont
Alice
Hot Creek
Indian Creek
Old Woman Creek
Lance Creek
Twentymile Creek
Lightning Cr.
Dry Creek
Bon Creek
Sand Creek
Cheyenne River
Alkali Creek
Beaver Creek
Thunder Creek
Shell Creek

ANGOSTURA RESERVOIR

STORET NO. 4603

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Angostura Reservoir is mesotrophic. It ranked seventh in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six water quality parameters*. One lake had less median total phosphorus, none had less median dissolved orthophosphorus, 21 had less and one had the same median inorganic nitrogen, two had less mean chlorophyll a, and four had greater mean Secchi disc transparency. Depression of dissolved oxygen with depth occurred at stations 1, 2, and 3 in July.

Survey limnologists did not observe any nuisance conditions during their sampling visits.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Angostura Reservoir was phosphorus limited at the time the sample was collected (04/24/74). The reservoir data indicate phosphorus limitation at all sampling stations and times with the exception of station 3 in September.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources contributed an estimated 13% of the total phosphorus load to Angostura

* See Appendix A.

Reservoir. The wastewater treatment plant at Edgemont contributed 12.9%, and septic tanks serving lakeshore dwellings contributed 0.1%. However, the facility at Edgemont discharges intermittently throughout the year, and additional study and a shoreline survey would be needed to determine the actual phosphorus contributions of these sources.

The phosphorus loading of 0.53 g/m^2/year is slightly more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). Because the reservoir is phosphorus limited during most of the year, phosphorus inputs should be minimized to the greatest practicable extent to maintain the present quality of this water body.

2. Non-point sources--Non-point sources contributed 87% of the total phosphorus load during the sampling year. The Cheyenne River contributed 81.3%, and Horsehead Creek contributed 2.0%. The ungaged minor tributaries and immediate drainage were estimated to have contributed 0.4% of the total.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 19.55 kilometers^2.
2. Mean depth: 9.1 meters.
3. Maximum depth: 18.3 meters.
4. Volume: 177.905 x 10^6 m^3.
5. Mean hydraulic retention time: 1.[illegible] years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Cheyenne River	22,558.9	3.840
Horsehead Creek	611.2	0.095
Minor tributaries & immediate drainage -	379.3	0.021
Totals	23,549.4	3.956

2. Outlets -

Irrigation diversion	-	1.758**
Cheyenne River	23,569.0***	2.120
Total	23,569.0	3.878

C. Precipitation****:

1. Year of sampling: 35.2 centimeters.
2. Mean annual: 40.7 centimeters.

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† Table of metric conversions--Appendix B.
†† Murphey, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Anonymous, 1976.
*** Includes area of lake.
**** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Angostura Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one or more depths at four stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 18.3 meters at station 1, 15.2 meters at station 2, 8.8 meters at station 3, and 1.5 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR ANGOSTURA RESERVOIR
STORET CODE 4603

PARAMETER	1ST SAMPLING (4/24/74) 4 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/15/74) 4 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/11/74) 4 SITES RANGE	MEAN	MEDIAN
TEMP (C)	7.1 - 10.9	9.4	9.6	15.8 - 25.3	22.3	24.3	17.9 - 18.6	18.4	18.4
DISS OXY (MG/L)	9.4 - 10.0	9.8	9.8	2.0 - 17.0	6.5	6.8	5.0 - 7.9	6.9	7.2
CNDCTVY (MCHOMO)	1344. - 1579.	1435.	1416.	1984. - 2530.	2335.	2430.	1869. - 1941.	1918.	1925.
PH (STAND UNITS)	****** -**********			7.7 - 8.2	8.0	8.0	7.8 - 8.1	8.0	8.1
TOT ALK (MG/L)	131. - 140.	134.	133.	140. - 151.	144.	142.	135. - 141.	137.	137.
TOT P (MG/L)	0.022 - 0.041	0.029	0.026	0.012 - 0.051	0.020	0.016	0.008 - 0.041	0.015	0.012
ORTHO P (MG/L)	0.003 - 0.008	0.004	0.004	0.003 - 0.015	0.008	0.007	0.003 - 0.009	0.005	0.004
NO2+NO3 (MG/L)	0.090 - 0.150	0.113	0.110	0.090 - 0.230	0.139	0.110	0.050 - 0.090	0.067	0.070
AMMONIA (MG/L)	0.040 - 0.090	0.052	0.050	0.030 - 0.130	0.069	0.060	0.040 - 0.100	0.061	0.050
KJEL N (MG/L)	0.200 - 0.600	0.347	0.300	0.300 - 0.900	0.367	0.300	0.200 - 1.100	0.580	0.700
INORG N (MG/L)	0.140 - 0.240	0.165	0.160	0.140 - 0.360	0.208	0.180	0.100 - 0.180	0.128	0.120
TOTAL N (MG/L)	0.320 - 0.720	0.460	0.430	0.390 - 1.060	0.506	0.470	0.260 - 1.150	0.647	0.750
CHLRPYL A (UG/L)	1.3 - 5.5	2.6	1.8	1.7 - 14.9	5.6	2.8	1.4 - 5.6	2.9	2.4
SECCHI (METERS)	0.9 - 4.6	2.6	2.4	0.4 - 3.0	2.0	2.4	0.3 - 2.7	1.2	0.9

B. Biological characteristics:

1. Phytoplankton

Sampling Date	Dominant Genera	Algal Units per ml
04/24/74	1. Chroomonas sp.	1,167
	2. Synedra sp.	367
	3. Ankistrodesmus sp.	133
	4. Asterionella sp.	67
	5. Cryptomonas sp.	66
	Other genera	1
	Total	1,801
07/15/74	1. Chroomonas sp.	493
	2. Carteria sp.	308
	3. Gyrosigma sp.	92
	4. Nitzschia sp.	92
	5. Merismopedia sp.	92
	Other genera	156
	Total	1,233
09/11/74	1. Cryptomonas sp.	276
	2. Chroomonas sp.	246
	3. Dinobryon sp.	61
	4. Phacus sp.	31
	5. Glenodinium sp.	31
	Other genera	30
	Total	675

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/24/74	1	1.4
	2	1.3
	3	2.3
	4	5.5
07/15/74	1	3.0
	2	1.7
	3	2.7
	4	14.9
09/11/74	1	2.0
	2	1.4
	3	5.6
	4	2.8

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.007	0.153	0.1
0.050 P	0.057	0.153	6.3
0.050 P + 1.0 N	0.057	1.153	12.7
1.0 N	0.007	1.153	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Angostura Reservoir was low at the time the sample was taken (04/24/74). Also, the increase in yield with the addition of phosphorus alone indicates that the reservoir was limited by phosphorus at that time. Note that the addition of nitrogen alone resulted in a yield which was no greater than that of the control.

The reservoir data indicate phosphorus limitation as well. The mean inorganic nitrogen/orthophosphorus ratios were 20/1 or greater at all sampling stations and times with the exception of station 3 in September (N/P = 12/1).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of March and May when two samples were collected. Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the South Dakota District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for the irrigation diversion and unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in the Cheyenne River at station A-1 (for the diversion) and in Horsehead Creek at station B-1 (for ZZ) and multiplying by the annual irrigation diversion and mean annual ZZ flows, respectively.

The operator of the Edgemont wastewater treatment plant provided monthly effluent samples; however, corresponding flow data were not available. Therefore, nutrient loads were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Edgemont	1,174	stab. pond	444.4	Cheyenne River

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Cheyenne River	8,360	81.3
Horsehead Creek	200	2.0
b. Minor tributaries & immediate drainage (non-point load) -	45	0.4
c. Known municipal STP's -		
Edgemont	1,330	12.9
d. Septic tanks** -	5	0.1
e. Known industrial - None	-	-
f. Direct precipitation*** -	340	3.3
Total	10,280	100.0
Lake outlet - Irrigation diversion	500	
Cheyenne River	600	
Total	1,110	

3. Net annual P accumulation - 9,180 kg.

* Treatment plant questionnaire.
** Estimate based on 22 lakeshore dwellings; see Working Paper No. 175.
*** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Cheyenne River	150,770	83.6
Horsehead Creek	3,450	1.9
b. Minor tributaries & immediate drainage (non-point load) -	765	0.4
c. Known municipal STP's -		
Edgemont	3,995	2.2
d. Septic tanks* -	235	0.2
e. Known industrial - None	-	-
f. Direct precipitation** -	21,105	11.7
Total	180,320	100.0

2. Outputs -

Lake outlet -	Irrigation diversion	82,165
	Cheyenne River	99,080
	Total	181,245

3. Net annual N loss - 925 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Cheyenne River	<1	7
Horsehead Creek	<1	6

* Estimate based on 22 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.53	0.47	9.2	loss*

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Angostura Reservoir:

"Dangerous" (eutrophic loading)	0.50
"Permissible" (oligotrophic loading)	0.25

* There was an apparent loss of nitrogen during the sampling year. This may have been due to nitrogen fixation in the lake, solubilization of previously sedimented nitrogen, recharge with nitrogen-rich ground water, unknown and unsampled point sources discharging directly to the lake, or underestimation of nitrogen loads. Whatever the cause, a similar nitrogen loss has occurred at Shagawa Lake, Minnesota, which has been intensively studied by EPA's former National Eutrophication and Lake Restoration Branch (Maleug et al., 1975).

V. LITERATURE REVIEWED

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Murphey, Duane G., 1974. Personal communication (reservoir morphometry). SD Dept. of Env. Prot., Pierre.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	4[illegible]9.111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	4.700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	LAKE BYRON	0.443	0.370	488.333	149.350	9.003	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.348	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.259	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.800	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.000	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
4627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
4628	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

.E DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	10'.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	WAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
4627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
4628	STOCKADE LAKE	30 (9)	40 (11)	73 (22)	50 (15)	5 (0)	27 (8)	225

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184
	4626	SAND LAKE	158

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

30<

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 06/04/76

LAKE CODE 4603 ANGOSTURA RES.

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 23569.0

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4603A1	23569.0	0.59	0.91	1.05	0.99	4.16	10.17	5.75	0.40	0.34	0.31	0.37	0.45	2.12
4603A2	22558.9	0.65	1.59	5.21	3.28	6.82	14.22	7.14	3.17	1.56	0.85	0.82	0.74	3.84
4603B1	611.2	0.0	0.0	0.057	0.227	0.142	0.227	0.283	0.142	0.057	0.0	0.0	0.0	0.095
4603ZZ	398.9	0.0	0.0	0.057	0.028	0.028	0.057	0.057	0.028	0.0	0.0	0.0	0.0	0.021

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 23569.0
SUM OF SUB-DRAINAGE AREAS = 23569.0

TOTAL FLOW IN = 47.43
TOTAL FLOW OUT = 25.49

NOTE *** AVERAGE YEARLY DIVERSION= 55,446,246 m^3

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4603A1	10	74	0.057	12	0.057				
	11	74	0.057	10	0.057				
	12	74	0.028	16	0.028				
	1	75	0.028	13	0.028				
	2	75	0.028	10	0.028				
	3	75	0.057	11	0.028	25	0.028		
	4	75	0.028	28	0.028				
	5	75	0.028	8	0.028	22	0.028		
	6	75	0.028	12	0.028				
	7	75	0.028	21	0.028				
	8	75	0.028						
	9	75	0.028	8	0.028				
4603A2	10	74	0.708	12	1.048				
	11	74	0.991	10	1.501				
	12	74	0.991	16	1.416				
	1	75	0.708	13	1.133				
	2	75	1.557	10	1.133				
	3	75	3.115	11	3.143	25	3.115		
	4	75	8.495	25	1.812				
	5	75	2.265	8	1.416	22	1.416		
	6	75	5.663	12	1.133				
	7	75	0.566	21	0.396				
	8	75	0.566						
	9	75	0.425	8	0.340				

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA

06/04/76

LAKE CODE 4603 ANGOSTURA RES.

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
460381	10	74	0.0	12	0.0				
	11	74	0.0	10	0.0				
	12	74	0.0	16	0.0				
	1	75	0.0	13	0.0				
	2	75	0.0	10	0.0				
	3	75	0.0	11	0.0	25	0.0		
	4	75	0.006	28	0.014				
	5	75	0.003	8	0.006				
	6	75	0.0	12	0.0				
	7	75	0.0	21	0.0				
	8	75	0.0						
	9	75	0.0	8	0.0				
460322	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.003						
	5	75	0.001						
	6	75	0.0						
	7	75	0.0						
	8	75	0.0						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/05/03

460301
43 20 3' 0 103 26 17.0 3
ANGOSTURA RESERVOIR
46047 SOUTH DAKOTA
090491

11EPALES 2111202
0065 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	13 55	0000	9.6		180	1425		131	0.040	0.600	0.120	0.003
	13 55	0005	9.6	10.0		1424		131	0.040	0.400	0.110	0.005
	13 55	0015	9.4	10.0		1418		132	0.050	0.200	0.120	0.004
	13 55	0030	8.1	10.0		1374		131	0.040	0.300	0.120	0.004
	13 55	0060	7.1	9.6		1344		133	0.060	0.300	0.130	0.004
74/07/15	13 55	0000	25.0	17.0	120	2476	8.10	140	0.050	0.400	0.090	0.013
	13 55	0005	25.0	7.8		2477	8.20	140	0.050	0.300	0.110	0.006
	13 55	0025	22.4	6.2		2298	8.10	142	0.060	0.300	0.140	0.011
	13 55	0035	16.8	3.8		2032	7.80	150	0.030	0.300	0.170	0.004
	13 55	0054	15.8	2.0		1984	7.70	151	0.130	0.400	0.230	0.009
74/09/11	11 25	0000	18.6	7.4	108	1937	8.09	136	0.050	0.400	0.060	0.006
	11 25	0005	18.6	7.9		1937	8.09	136	0.060	0.300	0.060	0.008
	11 25	0015	18.6	7.0		1937	8.09	136	0.040	0.200	0.060	0.003
	11 25	0025	18.2	5.8		1925	7.93	137	0.060	0.200	0.070	0.003
	11 25	0035	18.0	5.6		1919	7.87	141	0.090	0.200	0.090	0.003
	11 25	0049	17.9	5.0		1917	7.83	138	0.090	0.300	0.080	0.004

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/24	13 55	0000	0.028	1.4	
	13 55	0005	0.038		
	13 55	0015	0.022		
	13 55	0030	0.025		
	13 55	0060	0.029		
74/07/15	13 55	0000	0.016	3.0	
	13 55	0005	0.013		
	13 55	0025	0.012		
	13 55	0035	0.013		
	13 55	0054	0.033		
74/09/11	11 25	0000	0.012	2.0	
	11 25	0005	0.008		
	11 25	0015	0.008		
	11 25	0025	0.008		
	11 25	0035	0.009		
	11 25	0049	0.012		

STORET RETRIEVAL DATE 76/05/03

460302
43 18 35.^ 103 25 39.0 3
ANGOSTURA RESERVOIR
46047 SOUTH DAKOTA
090491

11EPALES 2111202
0053 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	14 35	0000	10.2		120	1456		133	0.050	0.400	0.120	0.003
	14 35	0005	10.0	10.0		1449		134	0.050	0.300	0.110	0.005
	14 35	0025	8.7	9.8		1392		134	0.050	0.400	0.120	0.008
	14 35	0049	8.0	9.8		1367		135	0.050	0.400	0.110	0.004
74/07/15	13 25	0000	24.6	7.0	120	2462	8.10	142	0.050	0.300	0.100	0.007
	13 25	0005	24.6	7.2		2456	8.20	141	0.050	0.300	0.100	0.007
	13 25	0020	24.3	6.8		2430	8.20	142	0.050	0.300	0.110	0.006
	13 25	0030	19.1	4.4		2138	7.90	145	0.080	0.300	0.190	0.007
	13 25	0050	16.1	3.2		2000	7.70	149	0.080	0.300	0.230	0.009
74/09/11	10 50	0000	18.4	7.6	48	1923	8.03	137	0.050	0.800	0.070	0.003
	10 50	0005	18.4	7.2		1927	8.13	140	0.070	0.700	0.080	0.004
	10 50	0015	18.4	7.0		1927	8.09	137	0.050	0.600	0.070	0.005
	10 50	0025	18.4	7.2		1927	8.09	138	0.050	0.700	0.070	0.006
	10 50	0040	18.4	7.0		1923	8.07	135	0.100	0.800	0.070	0.004

35^

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/24	14 35	0000	0.022	1.3	
	14 35	0005	0.030		
	14 35	0025	0.025		1.0
	14 35	0049	0.023		
74/07/15	13 25	0000	0.013	1.7	
	13 25	0005	0.017		
	13 25	0020	0.012		
	13 25	0030	0.013		
	13 25	0050	0.014		
74/09/11	10 50	0000	0.010	1.4	
	10 50	0005	0.011		
	10 50	0015	0.019		
	10 50	0025	0.017		
	10 50	0040	0.016		

STORET RETRIEVAL DATE 76/05/03

460303
43 17 27 N 103 23 27.0 3
ANGOSTURA RESERVOIR
46047 SOUTH DAKOTA

090491

:IEPALES 2111202
0033 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	15 00	0000	10.9			1420						
	15 00	0005	10.5	9.6	72	2414		133	0.050	0.300	0.100	0.005
	15 00	0015	9.7	9.8		1394		132	0.050	0.300	0.100	0.004
	15 00	0029	8.6	9.4		1385		132	0.050	0.300	0.100	0.003
74/07/15	13 05	0000	24.7	7.0	68	2494	8.00	134	0.090	0.300	0.150	0.003
	13 05	0005	24.8	7.0		2491	8.10	143	0.070	0.400	0.110	0.009
	13 05	0015	23.7	6.4		2421	8.00	143	0.060	0.300	0.100	0.009
	13 05	0021	21.8	3.8		2330	7.90	142	0.060	0.300	0.090	0.007
74/09/11	10 00	0000	18.5	7.4	24	1869	7.89	146	0.130	0.400	0.160	0.015
	10 00	0005	18.4	7.6		1879	8.05	137	0.070	1.100	0.050	0.009
	10 00	0015	18.5	6.2		1875	7.97	137	0.050	0.800	0.050	0.009
								136	0.050	0.700	0.050	0.008

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCOT LT REMNING PERCENT
74/04/24	15 00	0000	0.030	2.3	
	15 00	0005	0.026		
	15 00	0015	0.025		
	15 00	0029	0.029		
74/07/15	13 05	0000	0.026	2.7	
	13 05	0005	0.017		
	13 05	0015	0.024		
	13 05	0021	0.024		
74/09/11	10 00	0000	0.041	5.6	
	10 00	0005	0.029		
	10 00	0015	0.018		

STORET RETRIEVAL DATE 76/05/03

460304
43 17 18.0 103 27 42.0 3
ANGOSTURA RESERVOIR
46047 SOUTH DAKOTA
090491

11EPALES 2111202
0008 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/24	15 30	0000	10.9		36	1562		139	0.060	0.400	0.100	0.004
	15 30	0002	10.9	9.8		1562						
	15 30	0005	10.8	9.8		1579		140	0.050	0.380	0.090	0.004
74/07/15	12 40	0000	25.3	7.2	14	2530	8.00	142	0.080	0.900	0.160	0.003
74/09/11	10 35	0000	18.1	7.8	10	1941	8.13	139	0.040	0.900	0.070	0.004

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/24	15 30	0000	0.035	5.5	
	15 30	0005	0.041		
74/07/15	12 40	0000	0.051	14.9	
	12 40	0003			1.0
74/09/11	10 35	0000	0.013	2.8	

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/05/04

4603A1
43 21 20.C 103 25 25.0 4
CHEYENNE RIVER
46 7.5 ANGOSTURA RS
O/ANGOSTURA RESERVOIR 090491
BNK SAM 1.3 M DOWNSTRM FRM ANGOSTURA DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/11	09 30		1.760	1.200	0.030	0.005K	0.005K
74/11/10	09 10		1.760	0.300	0.025	0.005	0.005
74/11/16	11 00		1.840	0.600	0.030	0.005K	0.010K
75/03/25	09 00		1.005	0.750	0.035	0.005K	0.010K
75/04/28	10 10		0.360	0.700	0.030	0.010	0.010
75/05/08	10 10		0.300	0.550	0.035	0.005	0.010K
75/05/22	10 00		0.220	1.130	0.060	0.005	0.015
75/06/12	13 15		0.065	0.650	0.040	0.005K	0.010K
75/07/21	14 20		0.015	0.400	0.035	0.005	0.010K
75/09/08	17 00		0.720	0.500	0.040	0.005K	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

4603A2
43 18 19.0 103 33 43.0 4
CHEYENNE RIVER
46 7.5 CASCADE SPRS
T/ANGOSTURA RESERVOIR 090491
BRDG ON HWY 87 2 MI S OF CASCADE SPRINGS
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	10	20	0.280	0.500	0.010	0.005K	0.005
74/11/10	10	15	0.296	0.500	0.140	0.005	0.045
74/12/06	09	45	0.384	0.500	0.090	0.005K	0.010K
75/01/13	14	25	0.232	2.800	0.024	0.016	0.200
75/02/10	13	45	0.216	0.800	0.024	0.008K	0.010K
75/03/11	13	50	0.338	1.500	0.112	0.016	0.060
75/03/25	10	15	0.276	2.000	0.120	0.018	
75/04/25	11	30	0.260	1.550	0.140	0.025	0.340
75/05/08	13	45	0.170	0.800	0.030	0.015	0.100
75/05/22	08	30	0.220	1.000	0.045	0.005K	0.060
75/06/12	10	00	0.140	0.900	0.025	0.005K	0.090
75/07/21	13	20	0.050	0.250	0.030	0.005K	0.010
75/09/08	14	20	0.150	0.500	0.075	0.005K	0.035

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/04

460381
43 16 15.^ 103 20 45.0 4
HORSEHEAD CREEK
46 7.5 HOT SPRGS SE
T/ANGOSTURA RESERVOIR 090491
BRDG ON HWY 79 NEAR HORSEHEAD CEMETARY
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/04/28	10 30		0.005	1.400	0.055	0.020	0.060
75/05/08	10 30		0.010	1.050	0.040	0.010	0.050
75/05/22	09 20		0.040	0.950	0.055	0.007	0.090

STORET RETRIEVAL DATE 76/05/04

4603AA PD4603AA P001174
43 18 20.0 103 48 45.0 4
EDGEMONT
46 FALL RIVER CO.
T/ANGOSTURA RES 090491
CHEYENNE RIVER
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/01/07	10 30		0.160	11.000	0.370	1.800	2.700		
75/02/07	15 00		0.080			2.400	2.500		
75/03/07	10 30		0.080	11.000	0.400	2.700	2.900		
75/04/07	14 00		1.120	10.500	0.270	0.400	4.100		
75/05/07	14 00		0.150	14.500	0.180	2.300	3.900		
75/06/06	13 30		0.050	6.000	0.110	2.400	6.700		
75/07/02	14 00		0.050	7.900	0.025K	2.750	4.000		
75/08/07			0.050	10.000	0.050K	1.600	2.500		
75/09/08	14 45		0.025	12.000	0.039	2.300	3.500		
75/10/02	15 00		0.075	21.000	0.660	3.700	5.900		
75/11/07	15 30		0.115	5.000	4.000	2.500	3.200		
75/12/03			0.175	19.000	0.395	3.600	6.300		
76/01/07	15 00		0.025	18.000	2.700	2.100	4.600		

K VALUE KNOWN TO BE
LESS THAN INDICATED